PATENT ABSTRACTS OF JAPAN

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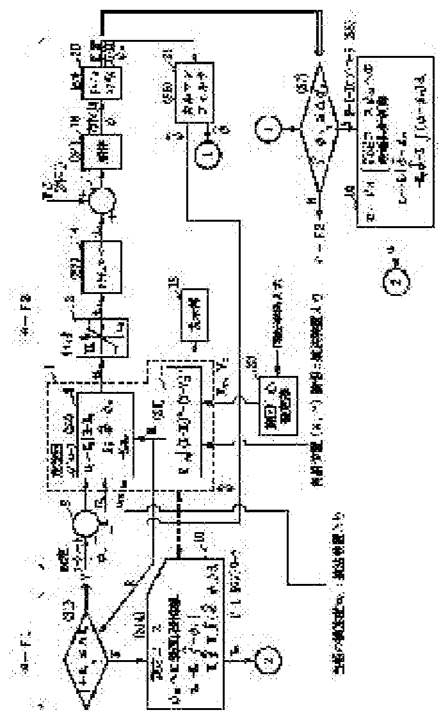
(54) AUTOMATIC STEERING GEAR



(57)Abstract:

PURPOSE: To predict an automatic course changing route, and reduce useless move by providing a means to accumulate a turning radius and a turning center in parallel coordinates axes with a target course, and a means to adjust a steering angle in such a way that a vessel locus draws an arc of the turning radius.

CONSTITUTION: An automatic steering gear is provided with a controller 1 as a steering angle adjusting means to set a difference between an inputted target course ψ02 and a current vessel course ψ01 at zero. In this case, a turning center setting part 23 is provided as a means to accumulate a turning radius RT and a turning center XT, YT in parallel coordinates axes with the target course ψ 02. In addition, a contant turning controller 9 is provided as a means to adjust a steering angle in such a way that a vessel locus draws an arc of the turning radius to the turning center after a distance from a vessel position to the turning center becomes similar to the rotation radius till the vessel cource reaches the target cource. An automatic cource changing route can thus be predicted correctly, and useless move in automatic course changing can be reduced.

* NOTICES *

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application]This invention is used for the automatic steering of a marine vessel. This invention is suitable for using for a minesweeper. In particular, it is related with the course stabilization technique under revolution or after revolution.
[0002]
[Description of the Prior Art]A conventional example is explained with reference to drawing 5. Drawing 5 is a block lineblock diagram of the autopilot of a conventional example. As shown in drawing 5, the autopilot of a conventional example sets up a target course (psi_{C2}) by a manual, and it carries out automatic steering of the ship by the P(proportionality)-I(integration)-D (differentiation) controller 10 so that an azimuth deviation (psi_{C2}-psi_m=deltapsi) with the present self-ship course (psi_m) may be set to 0. When the original azimuth deviation (deltapsi) is large, it is made for the load beyond regulation to have not taken for steering of the ship with command rudder angle u_C actual about the value beyond a certain default value which has formed the limiting circuit 12 since a big value is outputted at this time.
[0003]The output of the limiting circuit 12 It is told to the rudder of the hull 18, after [outside 1] gets across to the actuator 14, and actual rudder angle udelta is outputted and being added with disturbance element wdelta. Movement of a ship is measured as angle-of-direction psi_m by the gyrocompass 20.
[0004]
[External Character 1]
$\overline{u_c}$

This psi_m and this differential value [Outside 2] becomes a feedback signal to the P-I-D

controller 10.
[0005]
[External Character 2]
$\dot{\phi}_m$

[0006]
[Problem(s) to be Solved by the Invention]The problem of a conventional example is explained with reference to drawing 6. Drawing 6 is a figure showing the situation of veering of a conventional example, and the situation of vibration of the azimuth deviation after veering. As shown in drawing 6 (a), if the target course of a big azimuth deviation is set up, with the autopilot of a conventional example, it will circle according to the full limits of the limiting circuit 12. A steady state error and overshooting occur and after veering cannot realize smooth automatic veering, as shown in drawing 6 (b).
[0007]When the ocean space which the floating obstacle and others should avoid exists, this may pass actually the revolution orbit predicted at the beginning, and a different orbit, and has a big problem in that safe veering is unrealizable. Therefore, it will be necessary to carry out veering by a steersman's burden to veering in such ocean space, without depending on an autopilot, and the burden to a steersman will become large.
[0008]This invention is carried out to such a background and is a thing.
The purpose is to provide the autopilot which can realize automatic veering.
An object of this invention is to provide the autopilot which can predict an automatic veering orbit correctly. An object of this invention is to provide the autopilot which can reduce the useless motion at the time of automatic veering, and can aim at saving of a burn-out fuel.
[0009]
[Means for Solving the Problem]This invention is the autopilot provided with a means to adjust a rudder angle so that difference of an inputted target course (psi_{C2}) and the present self-ship course (psi_{C1}) may become zero.
[0010]A means by which a place by which it is characterized [of this invention] accumulates a center line of rotation (X_T, Y_T) on a turning radius (R_T) and a plane-coordinates axis with said target course (psi_{C2}) here, It is in a place provided with a means to adjust a rudder angle so that a self-ship locus may draw a circle by said turning radius to the center line of rotation until a self-ship course reaches said target course, since distance from a self-ship position to the center line of rotation became equal to said turning radius.
[0011]It is desirable to have an interruption control means which changes a target course (psi_{C2}) and a turning radius (R_T) which were accumulated in said means to accumulate, and a center line of rotation (X_T, Y_T).

[0012]It is desirable to include a means to incorporate a velocity-vector value of the hull center of mass system as a control parameter, and to calculate said rudder angle.
[0013]
[Function]A turning radius (R_T) and a center line of rotation are beforehand set up as accumulation information on a plane-coordinates axis with a target course (psi_{C2}). A rudder angle is adjusted so that a self-ship locus may draw the circle by said turning radius (R_T) to the center line of rotation.
[0014]The velocity-vector value of the hull center of mass system is incorporated as a control parameter, and it may be made to calculate said rudder angle. For example, when there is an ocean current from the direction which crosses a course, a hull flows into the black market in response to the influence of an ocean current. In order to perform steering compensated with a gap of the position by this side wash, a heading and a course are not necessarily in agreement. In such a case, it is not a heading and it is good to incorporate the velocity-vector value of the hull center of mass system as a control parameter, and to calculate a rudder angle.
[0015]
[Example]The composition of this invention example is explained with reference to drawing 1. Drawing 1 is a block lineblock diagram of this invention example device.
[0016]This invention is the autopilot provided with the controller 1 as a means to adjust a rudder angle so that the difference of the inputted target course (psi_{C2}) and the present self-ship course (psi_{C1}) may become zero.
[0017]The center-line-of-rotation set part 23 as a means by which the place by which it is characterized [of this invention] accumulates the center line of rotation (X_T, Y_T) on a turning radius (R_T) and a plane-coordinates axis with said target course (psi_{C2}) here, It is in a place provided with the constant turn controller 9 as a means to adjust a rudder angle so that a self-ship locus may draw the circle by said turning radius to the center line of rotation until a self-ship course reaches said target course, since the distance from a self-ship position to the center line of rotation became equal to said turning radius.
[0018]The target course (psi_{C2}) and turning radius (R_T) which were accumulated in the center-line-of-rotation set part 23, and the center line of rotation (X_T, Y_T) can interrupt below it and set up a new value besides the value beforehand accumulated according to the weather of the spot, and the existence and other factors of an obstacle. It has the indicator 13 as a means to display turning-radius R_T.
[0019]Next, operation of this invention example is explained with reference to drawing 2 thru/or

drawing 4. Drawing 2 is a flow chart which shows operation of this invention example. Drawing 3 is a block lineblock diagram of an autopilot when performing course keeping control in this invention example. Drawing 4 is a figure showing the situation of veering of this invention example, and the situation of vibration of the azimuth deviation after veering. In order to realize smooth automatic veering, automatic veering of this invention example comprises the four modes.

[0020]The mode 1 is what was provided so that the degree of constant speed (constant angular velocity) and constant radius revolution might not be started suddenly, The absolute value of the difference of the range from a center-line-of-rotation position (X_T, Y_T) to a self-ship position (X, Y) and desired turning-radius R_T is monitored, and if it becomes [whether it is equal to value deltaRc with this, and], it is made to start automatic revolution (S1).

[0021]A self-ship enters in a permission range ($|R-R_T|<=Ri$), and the mode 2 performs a constant radius and constant-speed degree revolution (S2-S6). With the constant turn controller 9 in the mode 2, it is a setting-out turn rate. [Outside 3] Information, including instruction turning-radius R_T, direction speed of hull pitch axis (cross current speed) u_{yb} of a self-ship, etc., is received, and it is about command rudder angle u_C. [0022]

[Equation 1]

$$u_C = -K_R \mid R - R_T \mid - K\dot{\phi} \ (\hat{\dot{\phi}} - \dot{\phi}_C) \ - K_V u_{yb} \qquad \cdots \ (1)$$

** -- it calculates like (S2). (1) First item $|R-R_T|$ is an absolute value of the difference of a turning radius and an instruction turning radius by a formula, and K_R is a feedback gain in the feedback term for making $-K_R|R-R_T|$ into $R=R_T$.

[0023]

[External Character 3]

$\dot{\phi}_C$

[Outside 4] is a point estimate of the output of Kalman filter 21 of the turn rate of a self-ship,

[0024]

[Equation 2]

$$-K\dot{\phi} \mid \hat{\dot{\phi}} - \dot{\phi}_C \mid$$

** [0025]

[Equation 3]

$$\dot{\phi} - \dot{\phi}_C$$

By the feedback term for it being alike and carrying out [Outside 5] is a feedback gain. $-K_v$ is a feedback gain in the feedback term for setting $K_v u_{yb}$ to $u_{yb}=0$.

[0026]

[External Character 4]

$\hat{\phi}$

[0027]

[External Character 5]

$K \dot{\phi}$

It is here and R is R=root. $[(X-X_T)^2+(Y-Y_T)^2]$ -- (2)

Come out, it is and they are X, Y, u_{xb}, and u_{yb}, [Outside 6] follows a following formula.

[0028]

[External Character 6]

$\dot{\phi}$

[0029]

[Equation 4]

$$m(\dot{u}_{xb} - u_{yb}\dot{\phi}) = T_{xb} \quad \cdots (3)$$

$$m(\dot{u}_{yb} + u_{xb}\dot{\phi}) = T_{yb} \quad \cdots (4)$$

$$\ddot{\phi} + a\dot{\phi} = bu\,\delta + bw\,\delta \quad \cdots (5)$$

$$\begin{pmatrix} u_x \\ u_y \\ u_z \end{pmatrix} = C_{Ib} \begin{pmatrix} u_{xb} \\ u_{yb} \\ u_{zb} \end{pmatrix} \quad \cdots (6)$$

$$X = X_0 \int_0^t u_x dt \quad \cdots (7)$$

$$Y = Y_0 \int_0^t u_x dt \quad \cdots (8)$$

It is here and C_{Ib} is, [0030]

[Equation 5]

$$C_{Ib} = \begin{pmatrix} \cos\phi\cos\theta & -\sin\phi\cos\theta+\cos\phi\sin\theta\sin\phi & \sin\phi\sin\phi+\cos\phi\sin\theta\cos\phi \\ \sin\phi\cos\theta & \cos\phi\cos\phi+\sin\phi\sin\theta\sin\phi & -\cos\phi\sin\phi+\sin\phi\sin\theta\cos\phi \\ -\sin\theta & \cos\theta\cos\phi & \cos\theta\cos\phi \end{pmatrix} \quad \cdots (9)$$

It is alike and is shown more. phi, theta, and psi are a roll angle of a hull, a helix angle, and a yaw angle, respectively. By the above, (xb, yb) are hull barycentric coordinate systems, and (u_{xb}, u_{yb}) are the speed (log output) in a hull coordinate system considering u as a hull velocity vector. X and Y are the navigation coordinate systems of a navigation system. X_0 and Y_0 are initial positions. [Outside 6] is a gyro output. The side-wash angle alpha shown in drawing 4 is alpha=tan $^{-1}$ (u_{xb}/u_{yb}).

It comes out. The upper limit of command rudder angle u_c is limiting circuit upper limit and a lower limit. [Outside 7] **[Outside 8] It is specified. Limiting circuit output [Outside 1] gets across to an actuator (S3), and it is outputted as actual rudder angle udelta. This gets across to a hull with disturbance wdelta, and with the gyrocompass 20, (S4) and hull movement are detected as psi_m (S5), and serve as an input of Kalman filter 21 (S6). This Kalman filter 21 [Outside 9] (Angle-of-direction point estimate) [Outside 4] A (turn rate point estimate) is outputted. The main functions in the mode 2 are constant radius revolution and constant-speed degree (turn rate regularity) revolution, and are expressed with (1) type.

[0031]

[External Character 7]

$\overline{u}_{cL}$

[0032]

[External Character 8]

$-\overline{u}_{cL}$

[0033]

[External Character 9]

$\hat{\phi}$

****** [that this mode 2 was completed], [0034]

[Equation 6]

$|\hat{\phi}-\phi_{c2}| \leqq \Delta\phi_c$

If it becomes and the absolute value of the difference of an angle-of-direction designated value

and setting-out direction psi$_{c2}$ after veering enters within tolerance level deltapsi$_c$, the mode 2 will be ended and will go into the mode 4. If, [0035]
[Equation 7]

$$|\hat{\phi} - \phi_{c2}| > \Delta\phi_c$$

It becomes, and if larger than deltapsi$_c$, it will return to the mode 2 (S7). This judgment function is the mode 3.
[0036]The mode 4 is the same as the P-I-D controller before going into the mode 2 (S10-S14), [0037]
[Equation 8]

$$u_C = -K_P(\hat{\phi} - \phi_C) - K_D\hat{\dot{\phi}} - K_I\int(\hat{\phi} - \phi_C)\,dt \quad \cdots (10)$$

It comes out and is constituted by shown optimum control gain K_p (proportionality), K_D (differentiation), and K_I (integration). This K_p, K_D, and K_I, [0038]
[Equation 9]

$$J = \int_0^\infty (X^TQX + u_C^2 r)\,dt \quad \cdots (11)$$

It is an optimal gain determined that it comes out and will make the valuation function to express into the minimum. It is here and is X,[0039]
[Equation 10]

$$X = \begin{pmatrix} \dot{\phi} \\ \phi \\ (\phi - \phi_C) \end{pmatrix} \quad \cdots (12)$$

It is ******. A course keeping control diagram is shown in drawing 3. Drawing 3 is a block lineblock diagram which performs course keeping control of this invention example. It is the almost same composition as the autopilot shown by drawing 5 of the conventional example. Differentiation is equipped with Kalman filter 21.
[0040]theta and r are a suitable dignity procession and a dignity constant, and K_p, K_D, and K_I are given with the solution to an optimal regulator well known for optimum control. The azimuth deviation at the time of veering performed with this invention example device is dramatically smooth as shown in drawing 4 (a), and as shown in drawing 4 (b), overshooting like a conventional example (drawing 6) is not generated. Therefore, the reliance rudder which is not preferred is not taken in steering.
[0041]The distance calculation to a target center line of rotation is calculated in the navigation

problem part, without calculating in an autopilot like this invention, and the same effect is acquired even if given by here as information.

[0042]

[Effect of the Invention]As explained above, according to this invention, smooth and stable automatic veering is realizable. A veering course can be predicted correctly. The useless motion at the time of automatic veering can be reduced, and saving of a burn-out fuel can be aimed at.

[0043]In particular, in the warship of a purpose like a minesweeper, effective mine countermeasures business is executable by automation of a constant radius and constant-speed degree revolution.

[Translation done.]